FP Project Description

Return to Full Proposal #: Y092260

Title: Development of a spatially-explicit crown allometry model

Project Description: SORTIE-ND is a spatially-explicit individual tree model that originated from the small scale disturbance model SORTIE (Pacala et al. 1996). SORTIE was designed to extrapolate fine-scale/short-term field measurements to large-scale, long-term forest dynamics (Pacala et al. 1996). In recent years, SORTIE-ND was parameterized and developed as a growth model for mixed forests in northwestern British Columbia (e.g. Kobe and Coates 1996, LePage et al. 2000, Canham et al. 2004, Astrup 2006) and modified to be better suited for dealing with management issues (Coates et al. 2004).

Growth models for silvicultural regimes such as underplanting, partial cutting, and utilization of secondary structure in mountain pine beetle (MPB) attacked stands should be: (1) capable of simulating mixed-species stands, (2) process-oriented due to limited relevant long-term data, (3) spatially-explicit due to the high degree of spatial heterogeneity, and (4) good at predicting understory tree growth. The stand level growth model SORTIE-ND possesses these features. Consequently, there is increasing interest in applying SORTIE-ND for simulation of complex stand growth in both boreal and sub-boreal British Columbia.

In a previous FSP project, we performed an evaluation of SORTIE-ND as a growth model for mixed aspen-spruce stands (Astrup 2006). SORTIE-ND was evaluated in terms of its conceptual structure, a sensitivity analysis was performed, and the model predictions were compared to independent permanent sample plot data. The evaluation suggested that SORTIE-ND is a suitable model for growth prediction in complex mixed-species stands. However, the evaluation also illustrated topics where further model development can improve the models robustness and predictive ability. The most critical topic for model development is related to crown allometry (crown diameter and crown length) (Astrup 2006). In SORTIE-ND, crown allometry affects the prediction of understory light, which is a critical resource for prediction of tree growth and mortality in complex stands. Thus, improvement of the crown allometry functions will improve the models ability to predict understory tree growth and mortality.

Crowns of similar sized trees do generally not overlap. Thus, crown radius of an individual tree is strongly dependent on local neighbourhood composition and structure. Crown shyness is the empty space that can be observed between individual crowns of similar-sized trees. Crown shyness is believed to be caused by breakage of branches caused by crown collisions during wind events (Rudnicki et al. 2002). Additionally, crown shyness is believed to be more evident in boreal and sub-boreal forests where branches are brittle during cold winter conditions (Lieffers et al. 2001). Crown depth is generally determined by light availability which in turn is dependent upon the surrounding tree neighbourhood structure.

In SORTIE-ND, crown length of an individual tree is a linear function of tree height while crown radius is a nonlinear function of diameter at breast height (DBH). These relationships are completely independent of the surrounding trees (Coates et al. 2004). Simultaneously, SORTIE-ND allows individual crowns to overlap. Thus, both crown radius and crown length are often overestimated in dense stands and underestimated in open stands. The result is a potential bias where understory light availability is underestimated in dense stands and overestimated in open stands. In SORTIE-ND, growth of individual understory trees is predicted based on light availability while mortality of individual understory trees is a function of recent growth (Coates et al. 2004). A bias in understory light predictions can consequently lead to a bias in understory tree growth and survival. To resolve this potential bias and make SORTIE-ND a more robust growth model for complex stands, we propose to create a new model of crown allometry.

Our primary objective is to develop and parameterize a distance-dependent model of crown allometry for SORTIE-ND. We intend to do this with a two year project. In year 1, we will collect the required data, develop, and test alternate statistical models. In the second year, we will incorporate the findings into SORTIE-ND, undertake model testing, and complete reporting and extension of our results.

Our secondary objective is to measure and describe crown shyness in complex stands. Some studies related to crown shyness have been undertaken in western Canada (Rudnicki et al. 2002), but never for mixed-species stands. Thus, an investigation of crown shyness is of academic interest. Additionally, the study of crown shyness can potentially be useful for implementing rules about crown shyness into stand-scale simulation models used in BC (e.g. SORTIE-ND, TASS, PrognosisBC, and FORECAST).

The results will be applied to forest management through the use of SORTIE-ND. Thus, our results can aid in predictions of growth of complex stands such as stands with mountain pine beetle attack, partial cutting, or variable retention.

References:

Astrup, R. 2006. Modeling growth of understory aspen and spruce in western boreal Canada. Ph.D. Dissertation, UBC, Vancouver.

Canham, C.D., LePage, P.T., and Coates, K.D. 2004. A neighborhood analysis of canopy tree competition: effects of shading versus crowding. Can. J. For. Res. 34:778-787.

Coates, K.D. Canham, C.D., Beaudet, M., Sachs, D.L. & Messier, C. 2003. Use of a spatially explicit individual-tree model (SORTIE/BC) to explore the implications of patchiness in structurally complex forests. For. Ecol. Manag. 186(1-3): 297-310.

Kobe, R.K. and Coates, K.D. 1997. Models of sapling mortality as a function of growth to characterize interspecific variation in shade tolerance of eight tree species of northwestern British Columbia. Can. J. For. Res. 27:227-236.

LePage, P.T., Canham, C.D., Coates, K.D. and Bartemucci, P. 2000. Seed sources versus substrate limitations of seedling recruitment in interior cedar-hemlock forest of British Columbia. Can. J. For. Res. 30: 415-427.

Lieffers, S.M., Lieffers, V.J., Silins, U. and Bach, L. 2001. Effects of cold temperatures on breakage of lodgepole pine and white spruce twigs. Can. J. For. Res. 31:1650-1653.

Pacala, S.W., Canham, C.D., Saponara, J., Silander, J.A., Jr., Kobe, R.K. et Ribbens, E. 1996. Forest models defined by field measurements: II. Estimation, error analysis and dynamics. Ecol. Monogr. 66: 1-43.

Rudnicki M., Lieffers, V.J. and Silins, U. 2002. Stand structure governs the crown collisions of lodgepole pine. Can. J. For. Res. 33: 1284-1244.

FP Project Objectives

Return to Full Proposal #: Y092260

Title: Development of a spatially-explicit crown allometry model

Project Objective: Current Year Objectives:
(1)To measure crown allometry and crown shyness in existing stem-mapped stands.
(2)To develop spatial and non-spatial models of crown allometry and crown shyness.

Long Term Objectives:
(1)To improve our understanding of crown allometry and crown shyness.
(2)To make SORTIE-ND a more robust growth model for use in complex stands.
(3)To further growth modeling in BC.

PRICEWATERHOUSECOOPERS

RIMS - Research Investment Management System

Home | Site Map | Help

Welcome Kirsteen Laing

[Sign Out]

Information | Full Proposal | My Account

FP Experimental Design and Methods

Return to Full Proposal #: Y092260

Title: Development of a spatially-explicit crown allometry model

Experimental Design and Methods: We will sample interior spruce, lodgepole pine, and subalpine fir in complex stands in the sub-boreal spruce (SBS) zone. All sampling will be performed in existing plots that have been stem-mapped for previous SORTIE-ND related FSP projects. Each tree in these plots has a recorded location but no data on crown allometry or crown shyness. The measurements from this project will provide the data on both crown allometry and crown shyness, while the existing measurements will provide the spatial information necessary for a distance-dependent analysis.

In the SBS, we currently have approximately 60 stem-mapped plots from previous SORTIE-ND related FSP projects. The plots are between 0.5 – 4 ha and have variable species compositions, age classes, and densities. For sampling, we will purposefully select 15 plots to obtain a wide range of age classes, densities, and species combinations. This will ensure that our data include sufficient variation in both dependent and predictor variables and allow us to develop relationships that are robust across different stand structures.

We will measure DBH for all trees in the stem-mapped stands and measure crown allometry and crown shyness for a sub-sample. We aim at a total sample size of 3000 individual trees with crown allometry and crown shyness measurements. The sample trees will be systematically sampled across a well spaced grid in each stand. For each sampled tree we will: (A) take one measurement of tree height and four measurements of crown length, (B) measure crown radius from aerial photographs, and (C) measure crown shyness from aerial photographs.

In the analysis, we will develop a static and a dynamic crown model. To initialize a simulation model to realistic starting condition, a static model is a requirement. To simulate the growth of a stand over time, (from the realistic starting condition generated with the static crown allometry and crown shyness functions) a dynamic crown model is often more appropriate. The link between the static and dynamic model is that the static model will provide the starting point (year 0 in a simulation) for the dynamic model.

For the static crown model, we will develop crown allometry equations that predict crown length and crown diameter as a function of local neighbourhood or stand conditions. The basic premise of the analysis is that crown dimensions diminish as above-ground and below-ground competition increases. For analysis, we will use an equation structure where a tree species- and size-dependent maximum crown dimension (crown diameter or crown length) is reduced according to competition. Competition will be quantified with a competition index. This analysis approach is widely used for predicting a wide host of tree attributed for different tree species (e.g. Uriate et al. 2004, Canham et al. 2006). We evaluate distance-dependent competition indices as predictors of crown length and crown radius. For distance-dependent competition indices, one of the key elements is the relationship between distance to a competitor and the competitive effect (Ledermann and Stage 2001). Competition indices generally consist of a function that sums the competitive effect of all surrounding competitors. In this summation function, the effect of each competitor is also weighted by the distance from the target tree (Ledermann and Stage 2001). In most distance-dependent competition indices, the effect (weight) of distance is arbitrarily determined rather than estimated from data. On the other hand, if parameter estimation is performed with maximum likelihood and optimization is performed with simulated annealing (Goffe et al. 1994) the distance effect can be estimated from data rather than arbitrarily determined (Canham et al. 2004). In the competition indices developed for this study, we will use maximum likelihood and simulated annealing to estimate the effect of distance between competitors.

For the dynamic crown model, we propose a model structure where the bottom of the live crown only can recede up the tree but never expand further down the tree. The movement of the crown up the tree will be a function of light availability at the bottom of the live crown. For all sampled trees, we will utilize light simulations to determine the light availability at the bottom of live crown. Thus, we will have data to determine the light threshold that determines the lower limit of the live crown. The crown radius will be able to expand a set amount every year until it reaches its maximum crown size or meet another crown. The maximum crown radius will be determined from open grown trees in the sampled stands. The annual expansion rate will be determined from exiting crown analysis data. In the case where the two crowns meet, the crowns will recede in order to achieve the appropriate level of crown shyness. This level of crown shyness will be determined from the field data and be a function of tree height and species.

The final part of the analysis relates to crown shyness. The basic premise is that crown shyness is caused by physical abrasion of close crowns and depends on tree species (brittleness of branches) and tree size (amount of sway and collision during wind events). We will develop statistical models that predict crown shyness between two trees as a function of their species and size. Specifically, we will fit the crown shyness data with multiple linear regressions and test for species differences and effects of tree size.

References:

Canham, C.D., LePage, P.T., and Coates, K.D. 2004. A neighborhood analysis of canopy tree competition: effect of shading versus crowding. Can. J. For. Res. 34: 778-787.

Canham, C.D., Papaik, M.J., Uriate, M., McWilliams, W.H., Jenkins, J.C. and Twery, M.J. 2006. Neighborhood analysis of canopy tree competition along environmental gradients in New England forests. Ecological Applications 16: 540-554.

Goffe, W.L., Ferrier, G.D., Rogers, J. 1994. Global optimization of statistical functions with simulated annealing. Journal of Econometrics 60: 65-99.

Ledermann, T. and Stage, A.R. 2001. Effects of competitor spacing in individual-tree indices of competition. Can. J. For. Res. 31: 2143-2150.

Uriate, M., Canham, C.D., Thompson, J., and Zimmermann, J.K. 2004. A neighborhood analysis of tree growth and survival in a hurricane-driven tropical forest. Ecological Monographs 74: 591-614.

Weigelt, A. and Jollifee, P. 2003. Indices of plant competition. J. Ecol. 91: 707-720.